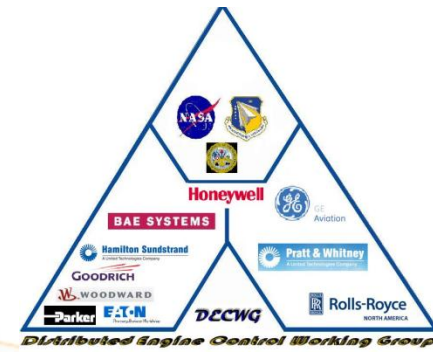


NASA GRC
Propulsion Controls & Diagnostics Workshop

9 December 2009
Cleveland, Ohio



Research Priority: Distributed Controls Architecture

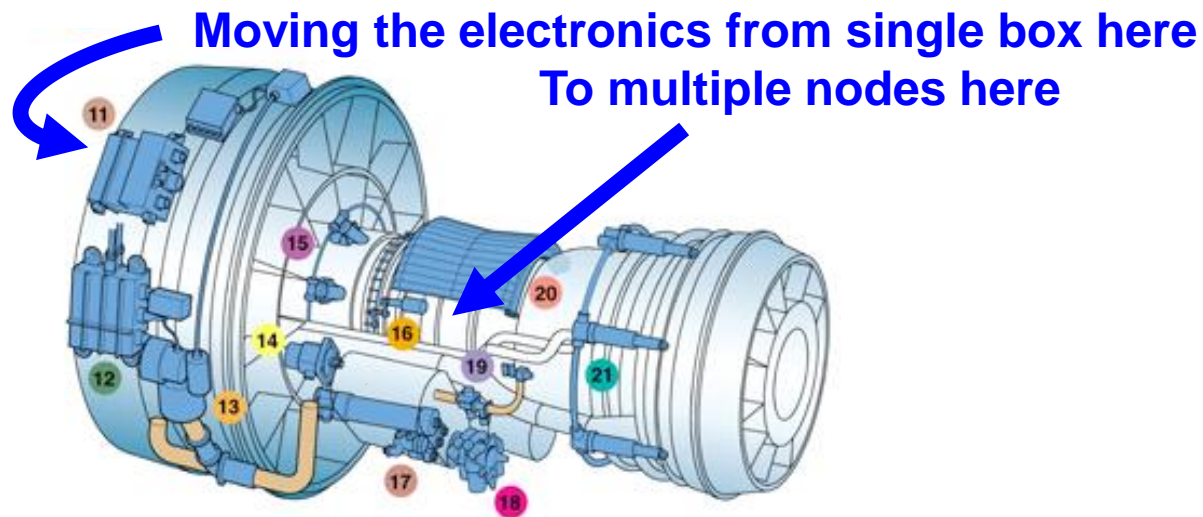
Dewey Benson
Honeywell

DECWG
Distributed Engine Control Working Group

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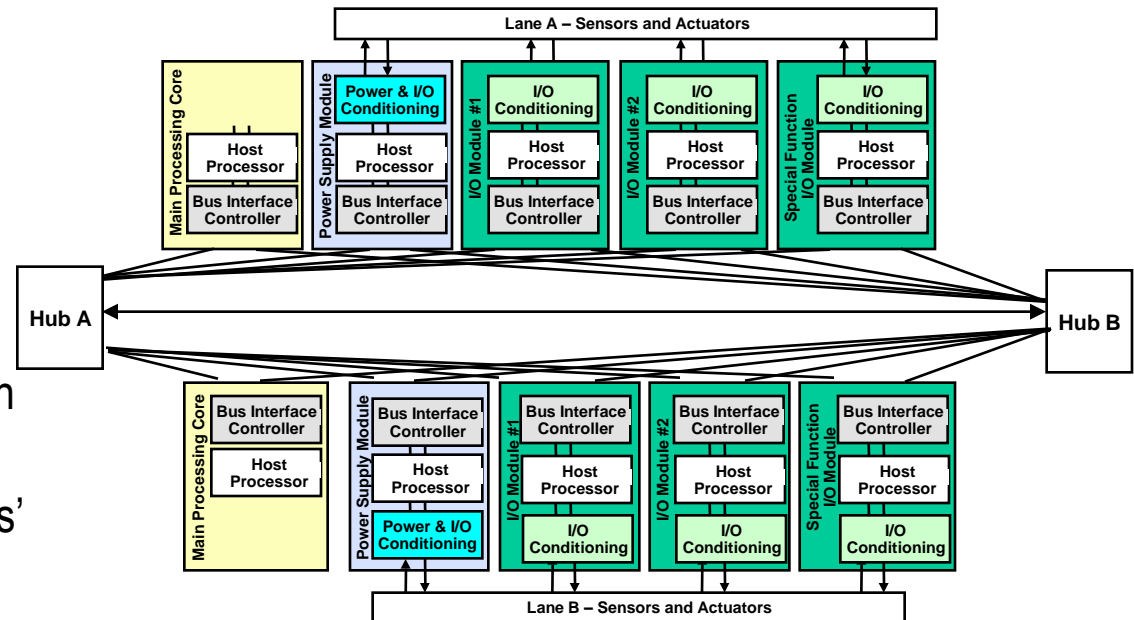
Presentation Outline

- Considerations for Distributed Engine Control
- Key Technologies
- Putting it all together – a system architecture



Distributed Engine Controls – Gen 1 Experience

Generation 1: Modular Aerospace Control (MAC)



- Born out of NASA funded research to investigate modular certification
 - Distributed, dual-lane configuration
- Based on TTP/C
 - Smart sensor and actuation 'nodes'

Lessons Learned

- MAC modules successfully re-used across multiple applications
- Network partitioning and composability demonstrated
- Great development schedule gains from systematic solutions to redundancy management
- Dispatch Drives Fault-Tolerance => more fault tolerance is better.
- **Network hub required to assure system integrity**

Hub is not conducive to physically distributed control system

Distributed Controls – Gen 1 Experience

■ Development

- Lower ~~Higher~~ cost for the first application
- ✓ Lower cost for each new application
- ✓ Faster development and qualification time
- ✓ New systems would be composed of mostly existing modules

■ Upgrades

- ◆ Faster, cheaper upgrades – easily modify or add new functionality
- ◆ Obsolescence will cost less - only modules affected are redesigned

■ Maintenance

- ◆ Better fault isolation
- ◆ Quicker turn-around-time
- ◆ Lower maintenance cost
- ◆ Lower spares provisioning

■ Lower Weight

- ◆ Drastic reduction in wiring harness weight

The Challenges

■ Key Technologies

- ◆ Network Availability & Criticality → Drives network and system design
- ◆ High Temperature Electronics → Cost vs Quantity
- ◆ Distributed computation → Drives module design
- ◆ Integrating smart sensors & actuators from different manufacturers

■ Resources → Architecture

- ◆ More computational power is needed to support:
 - ▶ Model-based Controls
 - ▶ Predictive Health Management (PHM)
- ◆ More sensors used to support PHM
- ◆ More actuation needed to support advanced engine cycles

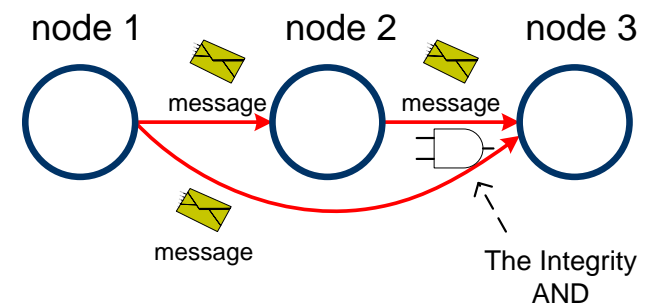
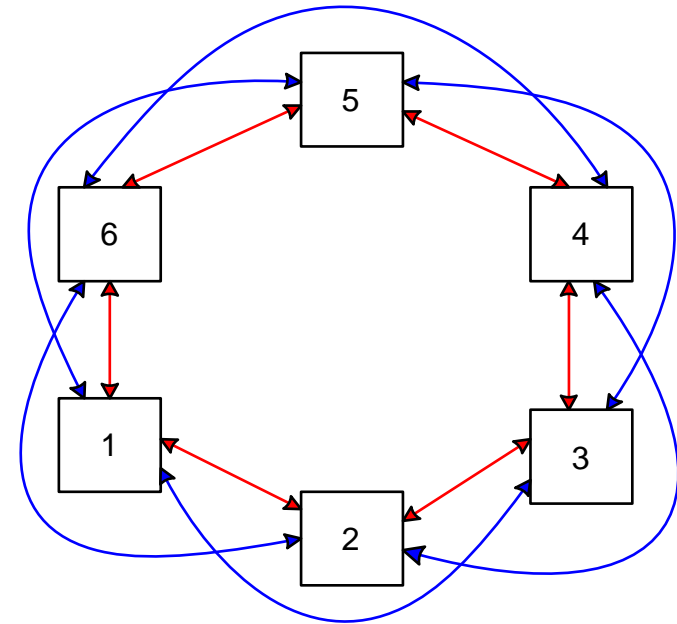
Key Technology – Networks

■ BRAIN Allows Integrity + Robustness

- Geographic brother's keeper guardian action
- Every node compares data forwarded from neighbor with data forwarded on skip link
- Enables independence without separate silicon
- Enables low complexity sensors and actuators

■ TT-GbE is Time Triggered Gigabit Ethernet

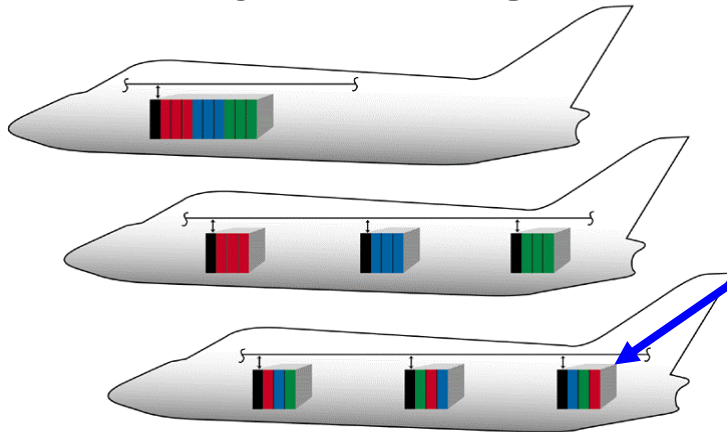
- 1 Gigabit copper or 10 Gigabit optical network
- Deploying on NASA CEV program for Orion Vehicle
- An aerospace-specific subset of Ethernet
- TT-GbE is a scaleable, highly deterministic, fault-tolerant Ethernet
- Compatible with avionics standard ARINC 664



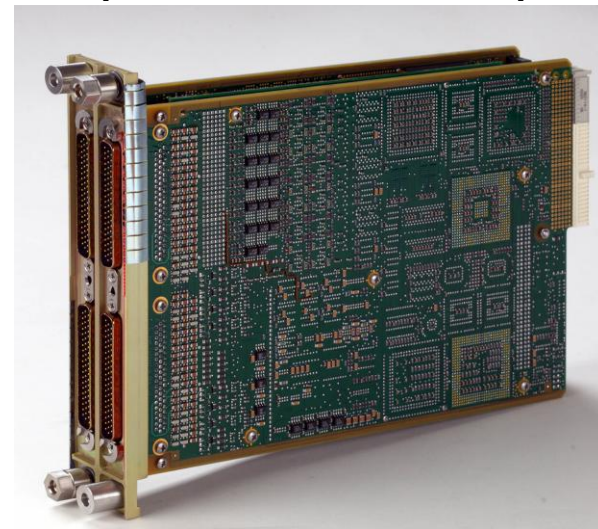
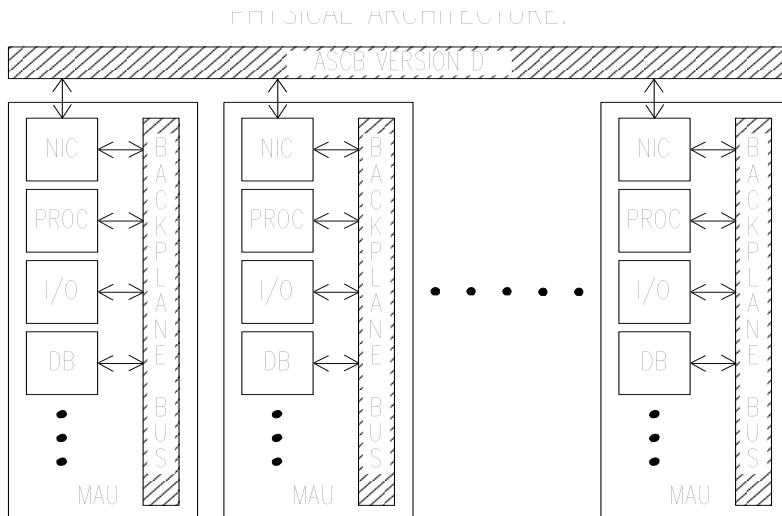
Concurrent Availability + Integrity Without Hub

Distributed Controls - The Avionics Experience

System Integration Through A 'Virtual Backplane'™



**MAU Module
(Dual Slot I/O Card)**



Avionics have been integrating multiple suppliers' equipment into a distributed system for years.

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The Avionics Experience - Integration of Multiple Suppliers

ATA Chapter	Function	Biz Jet	REG
21	Air Conditioning		
21	Pressurization		
24	Primary Power		
24	Secondary Distribution		
26	Fire Detection		
26	Fire Suppression		
27	Flight Controls		
28	Fuel Gauging		
28	Fuel Management		
29	Hydraulics		
30	Ice and Rain Protection		
32	Anti-skid Braking		
32	Nosewheel Steering		
32	Landing Gear Control / Proximity System		
33	Lighting		
38	Water and Waste		
49	APU Control		
49	APU Door Control		
52	Door Monitoring		
74	Ignition		
77	Engine Vibration Monitoring		
78	Thrust Reversers		
80	Starting		



Module Host



Software Host

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Application provider / Integration participants

- Smiths Industries
- BF Goodrich
- ELDEC
- ABSC
- Hydro-Aire
- Messier-Dowty Electronics
- Liebherr
- Vibro-Meter
- Hamilton-Sundstrand
- Kidde
- Whitaker
- Kieser
- Moog
- Vickers
- Parker
- Multiple Honeywell Sites

***Distributed Controls –
Do Not Fear***

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Key Technology – High Temp Electronics

Issues

- High temp electronics have been the “show stopper” in past attempts:
 - Lack of available parts to make a full distributed node
 - Difficulty of getting non-volatile memory to work at high temp
 - Cost of solutions
- User community wants the same cost as low temp electronics
- Compact size desired

Trade-offs

- Standard silicon solutions versus Silicon-On-Insulator (or Sapphire) or SiC
- Build up solutions from discrete parts or develop custom chips (ASICs)
- Temperature capability versus reliability

Specific application needs could dictate different solutions

High Temperature Part Availability Is Limited Compared to Bulk Si

Standard Catalog Products:

- HTOP01 Dual Precision Op Amp
- HT1104 Quad Operational Amplifier
- HT1204 Quad Analog Switch
- HTPLREG Voltage Regulators
- HT83C51 8-bit Micro Controller
- HT6256 256Kbit SRAM (32K x 8)
- HT506 Analog Multiplexer (16:1)
- HT507 Analog Multiplexer (8:2)
- HTCCG Crystal Clock Generator
- HTNFET N-channel power FET

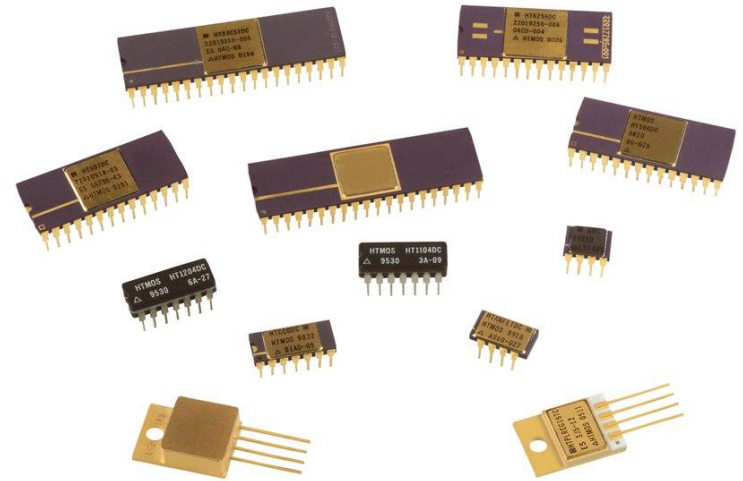
Custom Capabilities:

- Gate Arrays
- MCM (Multi-Chip Modules)
- High Temperature Design Services

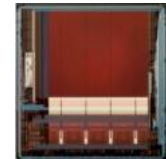
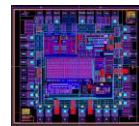
Products in Development:

- HTA/D Converter (12 and 18 bit)
- HTEEPROM
- HTFPGA
- Reconfigurable Processor for Data Acquisition (RPDA)

2 Million Device Hours Worth
Of Life Test Data



Key to flexibility:
Only High Temperature Non-volatile memory



Significant new parts developed from DOE funding

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Take-aways

How To Get The Most Out Of High Temperature Electronics

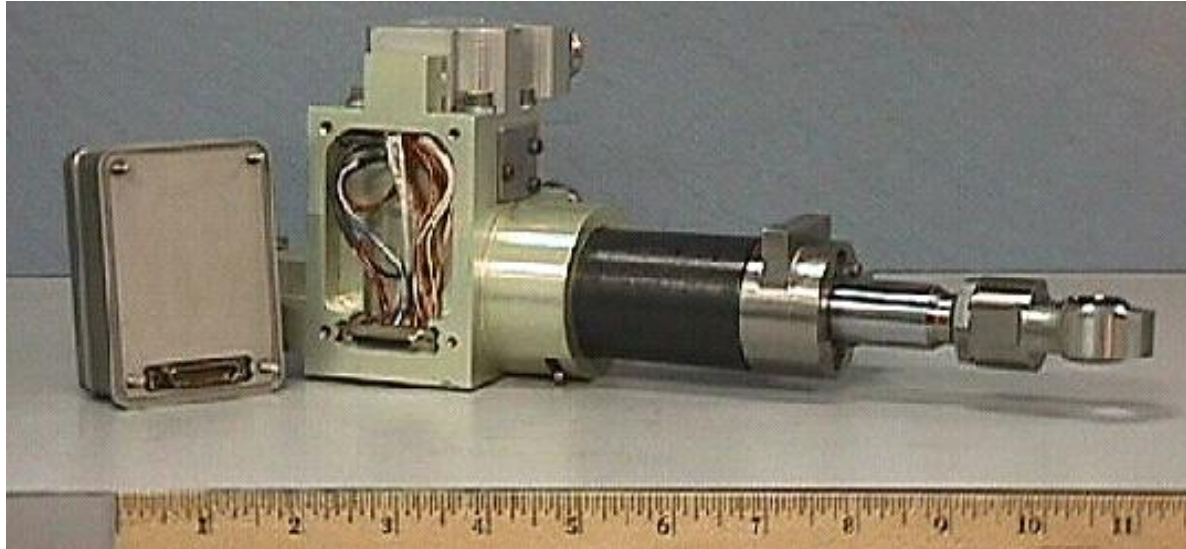
- Come at the solution from top and bottom
 - Users need to define a cost point that still yields benefits
 - Consensus design for high temp end products (node, data concen., etc)
 - Develop accurate estimate around consensus designs
- Identify a flexible architecture – few chips cover all end products
- Incorporate into as few parts as possible to minimize cost → Custom ASICs
- Users, suppliers, and gov't share cost to develop high temp nodes
- Shared access to resulting products
- Use DOE Deep Trek program as model

Need collaboration to overcome high development costs

First Attempt At High Temperature Electronics

High Temperature Servoactuator Electronic Interface Unit (EIU)

Circa 1999, Funded by Air Force Research Labs



- Tested at 200C
- Microcontroller w/ BIT
- 1553 Interface
- PWM Torque Motor Drive
- Position Sensor Interface
- 0.57 lbs
- 1.2 x 2.3 x 3.4 inches

Detractors in 1999 were cost and inflexibility due to lack of non-volatile memory

Non-Volatile Memory problem solved

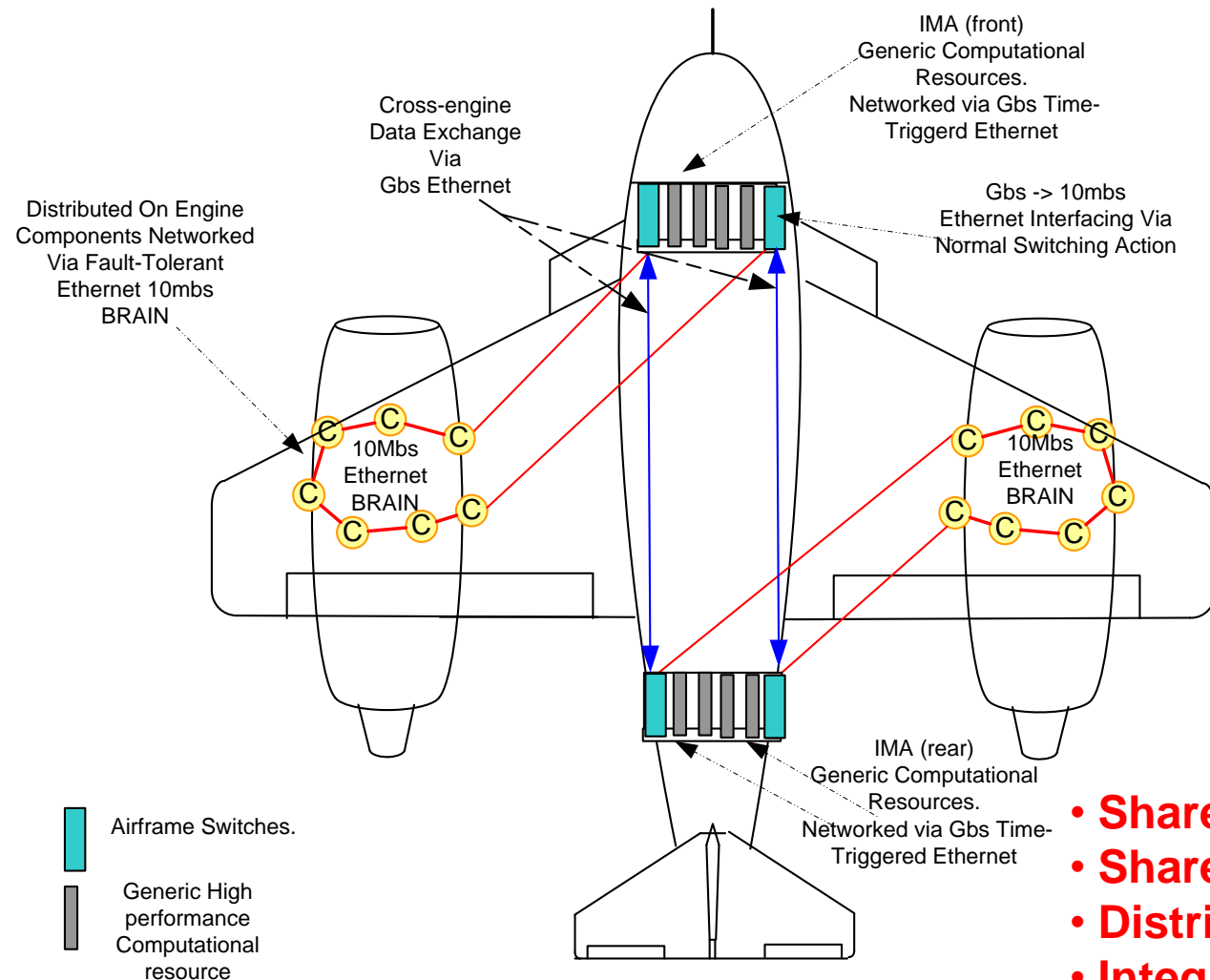
Hi-T Electronics Consortium being formed to solve cost

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Putting It All Together – A Distributed Architecture



- Shared computing resources
- Shared power supplies
- Distributed control
- Integrated Model-based controls
- + Vehicle Health Management

Summary

■ Most challenges are well understood and demonstrated:

- Distributed control
- Smart nodes
- Distributed computation
- High integrity, high availability networks

■ What's left?

- Define a common architecture
- Define a common reusable, scalable set of parts
- Move high temp electronics across the goal line!
- Build and demonstrate an end system

Other Research Priorities

- Verification of Adaptive Control Techniques
- Integrated Engine and Flight Controls
- Engine Health Management Contribution to Flight Management
 - ◆ Real-time flight assessment and fault accommodation
 - ◆ Continuous thrust available and fuel efficiency
 - ◆ Alternate flight plan solutions (i.e. return, divert, etc)
- Combined Fault Accommodation of Flight/Engine Controls
 - ◆ Control reconfiguration to maximize flight envelope
 - ◆ Recognition of unstable configurations
 - ◆ Invoke extreme measures to regain stable configuration (e.g. overthrust)
- Autonomous Civilian Flight
 - ◆ Single pilot cockpit → No pilot capability